

Food habits of *Podarcis filfolensis* (Reptilia, Lacertidae) on a small Mediterranean island during the dry season

Pierluigi Bombi¹, Leonardo Vignoli¹, Riccardo Scalera², Marco A. Bologna¹

Small islands are typically characterised by simplified ecosystems with low levels of complexity and reduced biodiversity. This condition may determine a scarcity of food resources which in turn can affect several aspects of the ecological features of the species, particularly their trophic niche (e.g., Gorman, 1979; Stephen and Krebs, 1986; Pérez-Mellado and Corti, 1993).

Predators are extremely sensitive to the complexity and structure of their ecosystems, and lacertids, which are characterised by small size and generalist habits, usually get over the poverty of resources by in some cases adding vegetal material in their diet (Ouboter, 1981; Sorci, 1990; Pérez-Mellado and Corti, 1993; Van Damme, 1999). The *Podarcis* species inhabiting the Mediterranean islands are a quite well studied group concerning adaptation to island conditions (e.g., Ouboter, 1981; Valakos, 1987; Pérez-Mellado and Corti, 1993). The rich background on phylogeny (e.g., Lanza and Cei, 1977; Capula, 1990, 1994; Oliverio et al., 1998, 2000; Harris and Arnold, 1999) and autoecology (e.g., Valakos, 1987; Rugiero, 1994; Sorci, 1990; Pérez-Mellado and Corti, 1993; Bombi and Bologna, 2002) of these lizards has stimulated the use of this genus as a model for eco-ethological studies. Moreover, this group includes a high number of very common species

(17 according to Oliverio et al., 2000), distributed on almost every small island of the Mediterranean basin: six *Podarcis* species are endemic to volcanic and continental Western and Eastern Mediterranean archipelagos (Oliverio et al., 2000); some other species are distributed on mainland areas and on the adjacent islands.

One of the less frequently studied species of this genus is *Podarcis filfolensis* (Bedriaga, 1876), endemic to the Maltese Archipelago and to the Linosa Island and the Lampione Islet (Pelagie Islands) (Lanza, 1973; Turrisi and Vaccaro, 1998; Corti and Lo Cascio, 1999). The only ecological researches carried out on this species concern the trophic habits (Sorci, 1990) and the population structure (Di Palma, 1991; Scalera et al., 2004).

The aim of this paper is to describe the food habits of *P. filfolensis* during the dry season, the hardest period in the Mediterranean Basin.

Linosa Island (Agrigento Province) is situated in the Mediterranean Sea, about 150 km SW from Sicily, and 140 km E from Tunisia (between 35°51'07"N and 35°52'34"N, and 12°50'43"E and 12°52'34"E). From a geological point of view, it is a volcanic island, with a basaltic belt and inner tuffaceous formations (Agnesi and Federico, 1995). The climate is semi-arid (cfr. Agnesi and Federico, 1995 for a review), the vegetation is characterised by xerophilic Mediterranean maquis (Brullo and Piccione, 1985) and the main cultivations include vineyards, Indian figs, cereals and lentils.

Field research was carried out in the second week of June 2000. Captures were made in a sampling area of about half a hectare, in the middle of the island, where specimens were captured by hand, noosed, or by pitfall traps (filled with a small quantity of water to attract them). Ten pitfall traps (cylindrical polyethylene containers, 8.7 cm wide and

1 - University of "Roma Tre", Department of Biology, Viale G. Marconi 446, 00146 Rome, Italy
e-mail: bombi@uniroma3.it

2 - Via V. Mazzola 38, 00142 Rome, Italy

15.0 cm deep) were placed randomly in the study area leaning them against stones or walls, and frequently checked. Each captured lizard was sexed, measured, painted on the back for short-time identification (to avoid recaptures), and released. All the specimens collected (14 females and 22 males) were adults (SVL males: 53.9-69.1 mm; SVL females: 53.3-68.4 mm). Moreover, the stomach contents, obtained by stomach flushing, (e.g., Legler, 1977; Legler and Sullivan, 1979; Pietruszka, 1987; Fitzgerald, 1989; James, 1990; Fields et al., 2000; Bombi and Bologna, 2002) were collected. The specimens were kept some hours in captivity before the release, in order to verify if injury occurred. No cases of injury were observed and marked specimens were recovered some days after the stomach flushing. All food samples obtained were examined in the laboratory using a stereomicroscope; all the food items found were identified to the finest reachable taxonomic level, then photographed with a digital camera. Pictures of items were analysed by Image Tool 3.00 software (University of Texas Health Science Center in San Antonio) and measured, approximating their volume to that of a spheroid or of a cylinder, according to the item shape (e.g., Ouboter, 1981; Duhnan, 1983; Valakos, 1987; Pérez-Mellado and Corti, 1993). The vegetable fragments appear in the stomach contents as dense sub-spherical masses, allowing to approximate their volumes to spheroids. Items were grouped according to the most convenient taxonomic level (usually the order), and the food data were utilised to describe the food spectrum of *P. filfolensis* both in terms of prey taxa and of relative quantities (number and volume). Simpson diversity index (Simpson, 1949) was utilized in order to estimate the degree of predatory specialisation of both females and males (Rugiero, 1994; Capula and Luiselli, 1994; Capizzi et al., 1995; Filippi et al., 1996; Angelici et al., 1997; Pita et al., 2002). The graphical technique developed by Costello (1990), modified by Amundsen et al. (1996), was utilized to represent the feeding strategy of this species. In the Amundsen plot, frequency of occurrence of each food item is plotted against its prey-specific abundance, defined as the proportion a prey item (*i*) comprises of all prey items in only predators that contain prey *i* (Amundsen et al., 1996). *U* test was used for statistical analysis. Cumulative-diversity curves (prey diversity plotted against number of stomachs) were elaborated for females and males to test whether the collected data were representative of the dietary spectrum of *P. filfolensis* and to avoid that intra-specific comparison could be biased by the effect of the sample size.

Five hundred and eighty-four items were recorded from the stomach contents examined. Five parasite cestoid specimens were also collected. The *ingesta* were determined as belonging to 20 prey type categories; one case of cannibalism by a female on a juvenile lizard was also observed (table 1). Both for females and males the cumulative-diversity curves indicated that a plateau phase was reached and prey composition was reliably assessed (fig. 1).

Table 1. Diet composition of male and female *Podarcis filfolensis*, expressed as volume (mm³) of ingested preys and as number of individuals of ingested preys.

Prey category	Females		Males	
	total volume	n° of individuals	total volume	n° of individuals
Acara	0.746	3	43.738	5
Araneae	10.907	6	45.845	9
Chilopoda	0	0	1.464	1
Coleoptera	180.595	13	152.232	12
Collembola	0	0	0.665	1
Diptera	7.991	10	52.916	13
Formicidae	468.639	71	781.414	96
Hemiptera	144.319	8	39.771	16
Heteroptera	122.567	2	55.767	5
Hexapoda	8.849	2	39.061	6
Homoptera	52.401	56	248.685	215
Hymenoptera	44.839	6	54.729	6
Lepidoptera	14.059	2	34.944	4
Odonata	46.111	1	0	0
Orthoptera	14.277	1	0	0
<i>Podarcis filfolensis</i>	520.911	1	0	0
Pseudoscorpiones	3.247	4	1.655	1
Psocoptera	0.474	2	0	0
Thysanoptera	0	0	0.154	1
vegetal material	485.207		3629.959	
debris	85.829		412.829	

Vegetal material consisted of fibres (70.7% of the whole volume of vegetal material), seeds (19.5%), stamens and other components (9.8%) of Asteraceae and Apiaceae (especially belonging to the genera *Anthemis* and *Daucus*).

Plants were eaten more often and in greater quantity by males (64.9% in volume) than females (21.9%), evidencing a certain degree of specialisation of males for herbivory (fig. 2). Indeed, the top right position of a food item in the Amundsen plot denotes a relative specialisation of the predator on this item. The volume of ingested vegetal material is significantly greater in males (*U* test_{f vs. m}: *U* = 33; *P* = 0.0191), and the trophic niche, with regards to the animal preys, is wider in females (Simpson_{n° of individuals}: *c*_f = 4.306; *c*_m = 2.719). Among the animal component, Formicidae, which were the dominant preys for both sexes, represented a greater percentage in males (50.3% in volume) than in

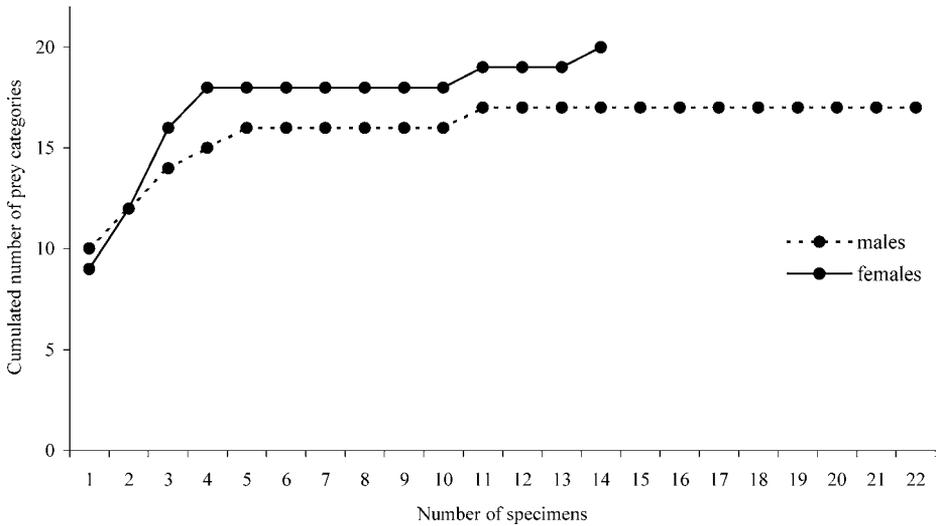


Figure 1. Plot showing numbers of *P. filfolensis* specimens from which stomachs were examined against cumulative number of prey categories recorded from their stomachs.

females (28.6%) (table 1). Debris represented a higher volume percentage of the stomach contents in males (7.4%) than in females (3.9%).

The previous ecological study on this species carried out by Sorci (1990) was limited to a general assessment of the trophic niche, analysed using data collected through a mixed sampling of both faecal and stomach contents. The food habits were compared to the availability of preys calculated on the basis of the taxonomical diversity of each group of invertebrates on Linosa Island, as cited by Zavattari (1960), therefore neglecting the real abundance of the species. Moreover indications on sampling season and sex of specimens were lacking. It is our opinion that, notwithstanding the good and updated knowledge concerning the arthropods fauna in Linosa (Massa, 1995), the only faunistic information does not permit to assess and to quantify the real availability of each prey.

According to our results, *P. filfolensis*, during the dry season, shows a generalist food strategy, eating animals belonging to several taxa and supplementing its diet with vegetal material. In fact, similarly to other insular populations of some congeneric species (Ouboter, 1981; Pérez-Mellado and Corti, 1993; Van Damme, 1999), this lacertid has a diet including a great vegetal

component, as underlined also by Sorci (1990). Nevertheless, fibres and seeds of Asteraceae and Apiaceae, the most common vegetal items found in stomach contents, are scarcely energetic food, difficult to assimilate. The vegetal component of diet is evidently greater in males than in females, but it is still unknown why there was an inter-sexual difference in terms of vegetal-eating by lizards at the study area. As concerns animal preys, the trophic niche is wider in females than in males but in both sexes Formicidae represents the dominant prey. Feeding on ants is already known in both mainland and insular species of *Podarcis* (e.g., Sorci, 1990; Pérez-Mellado and Corti, 1993; Capula and Luiselli, 1994; Grbac et al., 1998; Carrettero et al., 2001; Bombi and Bologna, 2002). These social insects represent an easy prey also in the smaller islands, probably because, even if suffer, as other animal groups, the insularity effects of reduction in species number (e.g., La Greca and Sacchi, 1957), they maintain a great abundance of individuals. In particularly at Linosa Island, a small number of species was cited [13 (Mei, 1995), vs. 100 of Sicily (Poldi et al., 1995)], but all of them are rich in individuals (M. Bologna and R. Scalera, pers. obs.).

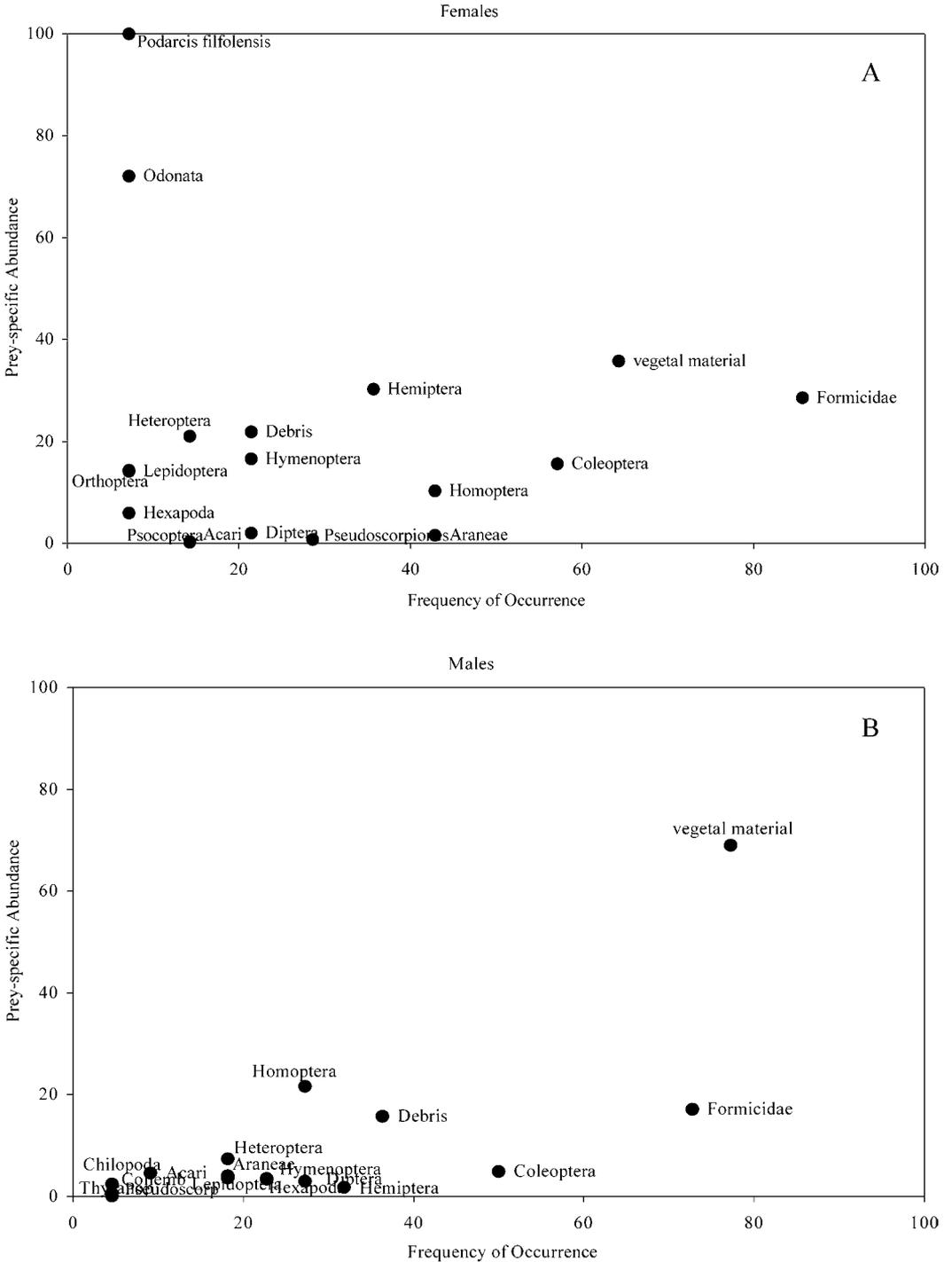


Figure 2. Amundsen plot illustrating the feeding strategy of females (A) and males (B) of *P. filfolensis*.

This study represents the first contribution on the trophic niche of *P. filfolensis* which uses a single sampling method, considering both food volume and prey diversity, and evidencing intersexual diet differences.

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References

- Agnesi, V., Federico, C. (1995): Aspetti geografico-fisici e geologici di Pantelleria e delle Isole Pelagie (Canale di Sicilia). In: Arthropoda di Lampedusa, Linosa e Pantelleria (Canale di Sicilia, Mar Mediterraneo), p. 1-22. Massa, B., Ed., Natur. Sicil. **19** (4), suppl.
- Amundsen, P.A., Gabler, H.M., Staldvik, F.J. (1996): A new approach to graphical analysis of feeding strategy from stomach contents data — modification of the Costello method. *J. Fish Biol.* **48**: 607-614.
- Angelici, F.M., Luiselli, L., Rugiero, L. (1997): Food habits of the green lizards, *Lacerta bilineata*, in central Italy and a reliability test of faecal pellet analysis. *Ital. J. Zool.* **64**: 267-272.
- Bombi, P., Bologna, M.A. (2002): Use of faecal and stomach contents in assessing food niche relationships: a case study of two sympatric species of *Podarcis* lizards (Sauria: Lacertidae). *Rev. Écol. (Terre Vie)* **57**: 113-122.
- Brullo, S., Piccione, V. (1985): Carta della vegetazione di Linosa — Sicilia. Consiglio Nazionale delle Ricerche, Roma.
- Capizzi, D., Luiselli, L., Capula, M., Rugiero, L. (1995): Feeding habits of a mediterranean community of snakes in relation to prey availability. *Rev. Écol. (Terre Vie)* **50**: 353-363.
- Capula, M. (1990): Struttura genetica di *Podarcis sicula*, *P. wagleriana* e *P. filfolensis*: aspetti tassonomici ed evolutivi (Reptilia, Sauria, Lacertidae). Unpublished Ph.D. Thesis, Università degli studi di Bologna.
- Capula, M. (1994): Evolutionary relationships of *Podarcis* lizards from Sicily and the Maltese Islands. *J. Zool. System. Evol. Res.* **32**: 180-192.
- Capula, M., Luiselli, L. (1994): Resource partitioning in a mediterranean lizard community. *Boll. Zool.* **61**: 173-177.
- Carretero, M.A., Llorente, G.A., Santos, X., Montori, A. (2001): The diet of introduced population of *Podarcis pityusensis*. Is herbivory fixed? In: Mediterranean Basin lacertid lizards a biological approach, pp. 113-124. Vicente, L., Crespo, E.G., Eds, ICN, Portugal.
- Corti, C., Lo Cascio, P. (1999): I Lacertidi italiani. Epos, Palermo.
- Costello, M.J. (1990): Predator feeding strategy and prey importance: a new graphical analysis. *J. Fish Biol.* **36**: 261-263.
- Di Palma, M.G. (1991): Censimento della popolazione di lucertole dell'isola di Linosa (Agrigento). Atti II Sem. ital. Censimenti Faunistici dei Vertebrati. Ric. Biol. Selvagg., Suppl. **16**: 207-209.
- Dunhan, A.E. (1983): Realized niche overlap. Resource abundance and intensity of interspecific competition. In: Lizard Ecology: studies of a model organism. R.B. Huey, E.R. Pianka and T. Schoener, Eds, pp. 261-280. Harvard University Press, Cambridge, USA and London, England.
- Fields, J.-R., Simpson, T.-R., Manning, R.-W., Rose, F.-L. (2000): Modifications to the stomach flushing technique for turtles. *Herp. Review* **31**: 32-33.
- Filippi, E., Capula, M., Luiselli, L., Agrimi, U. (1996): The prey spectrum of *Natrix natrix* (Linnaeus, 1758) and *Natrix tessellata* (Laurenti, 1768) in sympatric populations. *Herpetozoa* **8**: 155-164.
- Fitzgerald, L.A. (1989): An evaluation of Stomach Flushing techniques for crocodylians. *Journal of Herpetology* **23**: 170-172.
- Gorman, M.L. (1979): Island Ecology. Chapman and Hall, London.
- Grbac, I., Leiner, S., Perović, F. (1998): Thermoregulation and diet composition of insular populations of *Podarcis melisellensis* and *Lacerta oxycephala*. In: Abstracts of the Third International Symposium on the Lacertids of the Mediterranean basin, pp. 38. Janev, B., Grbac, I., Lupret-Obradović, S., Lazar, B., Eds, Cres, Hrvatska, 25-29.05.1998. Hyla-Croatian Herpetological Soc., Croatian Nat. Hist. Museum, Zagreb.
- Harris, D.J., Arnold, N. (1999): Relationships of Wall Lizards, *Podarcis* (Reptilia: Lacertidae) based on mitochondrial DNA Sequences. *Copeia* **1999**: 749-754.
- James, C.D. (1990): A refinement of the stomach-flushing technique for small scincid lizards. *Herp. Review* **21**: 87-88.
- La Greca, M., Sacchi, C.F. (1957): Problemi del popolamento animale nelle piccole isole mediterranee. *Annu. Ist. Mus. Zool. Univ. Napoli* **9** (3): 1-189.
- Lanza, B. (1973): Gli Anfibi e i Rettili delle isole circumsiciliane. *Lavori Soc. ital. Biogeogr. (N.S.)* **3** (1972): 755-804.
- Lanza, B., Cei, J.M. (1977): Immunological data on the taxonomy of some Italian lizards (Reptilia Lacertidae). *Monit. Zool. Ital. (N.S.)* **11**: 231-236.
- Legler, J.M. (1977): Stomach flushing: a technique for chelonian dietary studies. *Herpetologica* **33**: 281-284.
- Legler, J.M., Sullivan, L.J. (1979): The application of stomach-flushing to lizards and anurans. *Herpetologica* **35**: 107-110.
- Massa, B. (Ed.) (1995): Arthropoda di Lampedusa, Linosa e Pantelleria (Canale di Sicilia, Mar Mediterraneo). *Natur. Sicil.* **19** (suppl.): 909 pp.
- Mei, M. (1995): Hymenoptera Formicidae (con diagnosi di due nuove specie). Arthropoda di Lampedusa, Linosa e Pantelleria (Canale di Sicilia, Mar Mediterraneo). *Natur. Sicil.* **19** (suppl.): 753-772.

- Oliverio, M., Bologna, M.A., Monciotti, A., Annesi, F., Mariottini, P. (1998): Molecular phylogenetics of the Italian *Podarcis* lizards (Reptilia, Lacertidae). Ital. J. Zool. **65**: 315-324.
- Oliverio, M., Bologna, M.A., Mariottini, P. (2000): Molecular biogeography of the Mediterranean lizards *Podarcis* Wagler, 1830 and *Teira* Gray, 1838 (Reptilia, Lacertidae). J. Biogeogr. **27**: 1403-1420.
- Ouboter, P.E. (1981): The ecology of the island-lizard *Podarcis sicula salfi*: Correlation of microdistribution with vegetation coverage, thermal environment and food-size. Amphibia-Reptilia **2**: 43-257.
- Pérez-Mellado, V., Corti, C. (1993): Dietary adaptation and herbivory in lacertid lizards of the genus *Podarcis* from western Mediterranean islands (Reptilia: Sauria). Bonn. Zool. Beitr. **44**: 193-220.
- Pietruszka, R.D. (1987): On the application of stomach-flushing to Namib Desert lizards. Madoqua **15**: 73-78.
- Pita, C., Gamito, S., Erzini, K. (2002): Feeding habits of the gilthead seabream (*Sparus aurata*) from the Ria Formosa (southern Portugal) as compared to the black seabream (*Spondyliosoma cantharus*) and the annular seabream (*Diplodus annularis*). J. Appl. Ichthyol. **18**: 81.
- Poldi, B., Mei, M., Rigato, F. (1995): Hymenoptera Formicidae. In: Checklist delle specie della fauna italiana, p. 102. Minelli, A., Ruffo, S., la Posta, S., Eds, Calderini, Bologna.
- Rugiero, L. (1994): Food habits of the Ruin Lizard, *Podarcis sicula* (Rafinesque-Schmaltz, 1810), from a coastal dune in Central Italy. Herpetozoa **7**: 71-73.
- Scalera, R., Bombi, P., Mariottini, P., Bologna, M.A., Capula, M., Fornasari, L., Zava, B. (2004): Structure, dynamics and genetics of the Maltese Wall Lizard *Podarcis filfolensis* in Linosa island (Reptilia, Lacertidae). In: The conservation status of threatened amphibian and reptile species of the Italian fauna. Bologna, M.A., La Posta, S., Eds, Ital. J. Zool. **71** (Suppl. 1): 153-159.
- Simpson, E.H. (1949): Measurement of diversity. Nature **163**: 688.
- Sorci, G. (1990): Nicchia trofica di quattro specie di Lacertidae in Sicilia. Natur. Sicil. **4**: 83-93.
- Stephen, D.W., Krebs, J.R. (1986): Foraging theory. Monographs in Behaviour and Ecology. Princeton University Press. Princeton.
- Turrisi, G., Vaccaro, A. (1998): Contributo alla conoscenza degli Anfibi e dei Rettili di Sicilia. Boll. Accad. Gioenia Sci. Nat. **30**: 5-88.
- Valakos, E. (1987): The food of some Lacertidae in the insular ecosystems of the Aegean. Proc. Fourth Ord. Gen. Meet. S.E.H., Nijmegen, pp. 407-410.
- Van Damme, R. (1999): Evolution of herbivory in Lacertid lizards: effects of insularity and body size. J. Herpetol. **33**: 663-674.
- Zavattari, E. (1960): Biogeografia delle isole Pelagie. Rendic. Accad. Naz. dei 40 **11**: 1-471.

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